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C-E Electrical Hazards
Safety Verifications
Electrical Tests
Safety Assessments
Health Hazards

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This TOP provides general guidance for evaluating potential hazards during developmental testing (DT) of Communications-Electronics (C-E) Equipment/systems. Safety checklists, physical tests, observations, and examinations are presented for use during conduct of the test by all involved test personnel. Safety tests must be designed to comply with test item specifications. Electrical, mechanical, electromagnetic radiation, and other hazards during the safety test must be identified and contained.

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US ARMY ELECTRONIC PROVING GROUND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-105
*Test Operations Procedure 6-2-507 — 15 June 1981
AD No.

SAFETY AND HEALTH EVALUATION - COMMUNICATION/ELECTRONIC EQUIPMENT

Page

1. SCOPE. This TOP provides general guidance for identifying and evaluating potential hazards associated with Communication/Electronic Equipment/Systems. Due to the variety of equipment/systems subjected to developmental testing (DT), all of the information contained in this document may not apply. Each safety verification test program must be designed to assure compliance with the pertinent safety specifications and criteria. A complete evaluation is based on physical tests, examination of the test item with the use of safety test checklists and observations made by all participants during the test process. The intent of these tests is to identify and contain electrical, electromagnetic radiation, mechanical and other miscellaneous hazards to insure safe test procedures are followed.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities. No special facilities are required.

2.2 Instrumentation.

ITEM	MAXIMUM ERROR OF MEASUREMENT
Multimeter	±5% of full scale
Field intensity meters	±5% of full scale
Surface Thermometers (Thermocouple)	±0.5% of ±1° reading
Light meters	±10% absolute
Sound level meter	±5% of full scale
Air contamination test sets	±5% of full scale

*This TOP supersedes MTP 6-2-507, March 1967.
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3. PREPARATION FOR TEST.

3.1 Preliminary Safety Review and Documentation Preparation.

a. Ensure that the developer's safety assessment report has been received. In accordance with [1]AR 70-10 and [2]AR 385-16 this report must be available sixty-five (65) days prior to the start of a DT. All known safety and health hazards identified by the contractor or developer will be documented in this safety assessment. When non-ionizing radiation is a factor involved in a programmed test, the developer must coordinate with the USA Environmental Hygiene Agency (USAEHA) and obtain a health hazard assessment. Reference [3]AR 40-5 and [2]AR 385-16. Once these two evaluations have been received, the documented hazards must be considered during the DT.

b. Ensure that a safety subtest has been developed for all DT at the proving ground.

c. Review the system support package, all instructional material, literature, draft technical manuals and schematics.

d. Ensure that a suitable test site and/or test facilities are surveyed for conducting DT.

e. Schedule an initial examination of the test item with the maintenance evaluator, human factors engineer, and safety engineer present. Discuss all the safety related problem areas of the test item to enable test participants to observe performance tests and field operations, and identify all hazards associated with the test item. Use the appropriate checklists appended to this TOP throughout all operations during the DT cycle. Direct observation to specific potential hazards provided from the check lists.

f. Ensure required Standing Operating Procedures (SOPs) and TOPs are developed and available for use.

3.2 Operator Training and Familiarization.

a. Ensure that the required new equipment operator training is conducted by the developer or contractor.

b. Conduct a pretest briefing to all test participants. The briefing shall include the hazards contained in the safety statement and the initial safety survey.

c. Review, by all test personnel, any safety related SOPs pertaining to the test item.

1. AR 70-10, Test and Evaluation during Development and Acquisition of Materiel, 29 August 1975.
2. AR 385-16, System Safety Engineering and Management, 1 December 1980.
3. AR 40-5, Health and Environment, 25 September 1974.

3.3 Receipt Inspection. An initial safety inspection of the test item shall be performed by the safety engineer, maintenance evaluator and human factor engineer prior to conducting all other tests. The appropriate portion of the checklist of appendix C will provide a guide to the potential hazards that could be encountered. Satisfactory resolution on all potential hazards will be accomplished prior to the commencement of DT.

4. TEST CONTROLS.

4.1 Test Item Configuration. Test items are tested in the configuration and condition in which they are expected to be deployed and operated by the Field Army.

4.2 Procedures for Accumulating Data. The results of initial safety inspection, hazard analysis of all test results, interviews, and operator reports of unsafe conditions will be used as methods of accumulating data.

4.3 Personnel. The test officer will participate in the accumulation of data. The safety engineer will analyze the data using hazard analysis and risk assessment procedures described in appendix A.

4.4 Risk Assessment. Hazard analysis and risk assessment procedures will be used to establish the degree of hazard. The probability that the mishap will occur and the severity of potential consequences will be considered in this evaluation. Risk assessment procedues are described in appendix A.

4.5 Data Required. Record the following:

a. Test Item. Nomenclature, serial number, and manufacturer; and identification of, and any modification to, the equipment or shelter in which the test item is mounted.

b. Instrumentation. Type, nomenclature, accuracy, data of last calibration, and location of each piece of instrumentation.

5. PERFORMANCE TESTS.

5.1 Method.

a. Specific safety and health evaluations subtest will be designed to evaluate all safety and health criteria.

b. Perform an initial evaluation of the potential hazards in the system under test as described below, using the checklist of appendix C prior to operating the test item.

c. Repeat the safety examination and record each appropriate element in the checklist at selected points in the test. Determine if the inherent safety of the system is affected by wear and operation incident to the accomplishment of other test phases (reliability, endurance, etc.).

d. Make continuous observations during test operations conducted to evaluate performance and reliability factors, and identify potential hazards to personnel and equipment not included in the special tests of the equipment under "worst case" conditions. The safety engineer shall review the adequacy of all design features intended to eliminate or minimize potential hazards, and investigate any potential hazards which may occur or become more serious because of additional operating hours.

e. Hazard analysis and risk assessment are conducted in conjunction with the acquisition of results from safety test, safety inspections, operator comments, a review of the draft technical manual, safety-related observations, and results from other subtests. The hazards that are identified are evaluated using the techniques described in appendix A.

5.1.1 Electrical and Electronic Hazards. Examine all instructional material; determine the location of all potential electrical hazards, and ensure that these hazards are clearly indicated and the appropriate precautionary notices and instructions are provided.

The test item shall be thoroughly inspected for safety during the initial safety inspection and during all phases of testing and evaluation. Comments and observations from equipment operators should be obtained.

5.1.2 Mechanical Hazards. Carefully examine all instructional material to determine potential mechanical hazards.

Perform a thorough test item safety inspection and observe the item throughout all testing and evaluation phases. Solicit the comments and observations of equipment operators and maintainers.

5.1.3 Health Hazards. Throughout the conduct of the test, note any conditions that might be physiologically hazardous to the operation or maintenance personnel. Specific industrial hygiene measurements should be made to verify suspected hazards.

5.2 Data Required. Tabulate the results of each examination and each physical test related to safety of the test item. Record the conditions of use from the log book, such as temperature, humidity, and other environmental data. Record and describe any features that require further investigation, including any hazards that could occur or increase as a result of increased operating hours.

6. DATA REDUCTION AND PRESENTATION.

6.1 Data Presentation. The format shown in figure 1, appendix A will be used to present all conditions which are hazardous to personnel, equipment, and property.

6.2 Narrative Description of Test Results. Sufficient narrative comments will be included on each condition to provide background information to be used in the analysis of test results.

6.3 Analysis. Each hazardous condition will be analyzed as outlined in appendix A to determine the severity and probability of the hazard. For electrical and electronic hazards, additional guidance is contained in appendix B for assigning hazard severity and probability levels. The classification guide in [4]TOP 1-1-012 will be used to classify deficiencies, shortcomings, and suggested improvements[5].

Recommend changes to this publication should be forwarded to Commander, US Army Test and Evaluation Command, ATTN: DRSTE-AD-M, Aberdeen Proving Ground, Maryland 21005. Technical information may be obtained from the preparing activity: Commander, US Army Electronic Proving Ground, ATTN: STEEP-MT-T, Fort Huachuca, Arizona 85613. Additional copies are available from the Defense Technical Information Center, Cameron Station, Alexandria, Virginia 22314. This document is identified by the accession number (AD No.) printed on the first page.

4. TOP 1-1-012, Classification of Deficiencies and Shortcomings, 1 April 1979.
5. DARCOM Regulation 385-12, Life Cycle Verification of Materiel Safety, 29 June 1972.

APPENDIX A

EQUIPMENT OPERATION HAZARD ANALYSIS

Operating hazard analysis may be performed during development testing to identify hazards associated with equipment, procedures, and personnel. Data from all development subtests can be used to prepare the Equipment Operation Hazard Analysis.

Figure 1 is typical Equipment Operation Hazard Analysis Worksheet. This worksheet is designed to assure a complete analysis and classification of hazards that have been identified. The following instructions apply to the worksheet:

a. Hazard Description - Describe the personnel error, environmental condition, design inadequacy, procedural deficiency, system or component malfunction that presents a hazard to personnel, equipment, or property.

b. Hazard Effect - Describe the worst potential consequences to operating or maintenance personnel, equipment or property should the hazard continue to exist.

c. Hazard Severity - Categorize the hazard in accordance with the provisions of [6]MIL-STD-882. This is accomplished in two parts. First, consider the hazard effect described in the second column of the worksheet. Based on this description, assign one of four possible hazard categories shown below:

(1) CATEGORY I - CATASTROPHIC: May cause death or system loss.

(2) CATEGORY II - CRITICAL: May cause severe injury, severe occupational illness, or major system damage.

(3) CATEGORY III - MARGINAL: May cause minor injury, minor occupational illness, or minor system damage.

(4) CATEGORY IV - NEGLIGIBLE: Will not result in injury, occupational illness, or system damage.

After assigning the hazard severity, then the qualitative probability that the hazard effect will occur in a specific individual item or in the Army inventory must be assigned. One of six possible hazard probability levels must be assigned from those listed below:

6. MIL-STD-882A, System Safety Program Requirements, 28 June 1977.

HAZARD DESCRIPTION	HAZARD EFFECT	HAZARD CATEGORY	HAZARD CONTROLS AND REMARKS

Figure A-1. Typical Equipment Operation Hazard Analysis Worksheet.

Hazard Probability

Descriptive Word	Level	Specific Individual Item	Inventory
Frequent	A	Likely to occur frequently.	Continuously experienced
Reasonably Probable	B	Will occur several times in life cycle of an item.	Will occur frequently
Occasional	C	Likely to occur sometime in life cycle of an item.	Will occur several times
Remote	D	So unlikely it can be assumed that this hazard will not be experienced.	Unlikely to occur but possible
Extremely Improbable	E	Probability of occurrence cannot be distinguished from zero.	So unlikely it can be assumed it will not be experienced
Impossible	F	Physically impossible to occur.	Physically impossible to occur

Together, the hazard severity and the hazard probability completely classify the hazard in accordance with MIL-STD-882A. For example, a hazard that could occasionally result in a critical mishap is a Category II-C hazard. This designation is entered in the third column of the worksheet.

To classify the hazard as a deficiency, shortcoming, or suggested improvement, the Hazard Classification Guidelines provided as figure 2 should be used. This classification is also entered in the third column of the worksheet.

d. Hazard Controls and Remarks - Comments relative to what should be done to prevent the hazard or protect against the consequences are included in the fourth column of the worksheet.

			HAZARD PROBABILITY					
			FREQUENT	REASONABLY PROBABLE	OCCASIONAL	REMOTE	EXTREMELY IMPROBABLE	IMPOSSIBLE
SPECIFIC INDIVIDUAL ITEM →			Likely to occur frequently	Will occur several times in life of item	Likely to occur sometime in the life of item	So unlikely, can be assumed that this hazard will not be experienced	Probability of occurrence cannot be distinguished from zero	Physically impossible to occur
FLEET OR INVENTORY →			Continuously experienced	Will occur frequently	Will occur several times	Unlikely to occur, but possible	So unlikely, can be assumed that this hazard will not be experienced	Physically impossible to occur
			A	B	C	D	E	F
HAZARD SEVERITY	CATASTROPHIC - May cause death or system loss	I	DEFICIENCY	DEFICIENCY	DEFICIENCY	DEFICIENCY	SUGGESTED IMPROVEMENT OR ACCEPTABLE	ACCEPTABLE
	CRITICAL - May cause severe injury or illness, or major system damage	II	DEFICIENCY	DEFICIENCY	DEFICIENCY	SHORTCOMING	SUGGESTED IMPROVEMENT OR ACCEPTABLE	ACCEPTABLE
	MARGINAL - May cause minor injury or illness, or minor system damage	III	DEFICIENCY	SHORTCOMING	SHORTCOMING	SUGGESTED IMPROVEMENT	SUGGESTED IMPROVEMENT OR ACCEPTABLE	ACCEPTABLE
	NEGLIGIBLE - Will not result in injury or illness, or system damage	IV	SHORTCOMING	SUGGESTED IMPROVEMENT	SUGGESTED IMPROVEMENT	SUGGESTED IMPROVEMENT OR ACCEPTABLE	SUGGESTED IMPROVEMENT OR ACCEPTABLE	ACCEPTABLE

Figure A-2. Hazard Classification Guidelines.

APPENDIX B

CLASSSIFICATION OF ELECTRONIC AND ELECTRICAL SHOCK HAZARDS

These guidelines apply to the analysis of electronic and electrical hazards in electronic equipment and components to which [7]MIL-STD-454G applies.

Accidental contact by operating and maintenance personnel with electrically energized circuits in electronic equipment may result in sufficient current flow through the body to cause serious injury or death. Requirement No. 1 of [7]MIL-STD-454G presents the design requirements for electrically energized equipment to minimize the danger they present to personnel. These requirements are largely assessed when the checklist for electrical and electronic hazards found in Appendix C is used to evaluate electronic equipment.

Each hazard that is identified when using the checklist or any other test must be categorized in accordance with [6]MIL-STD-882A, and subsequently classified as a potential deficiency, shortcoming, or suggest improvement. In addition to voltage considerations, estimates should also be made of the amount of current that could flow through the body, and of the corresponding probable effects of shock.

Figures B-1 and B-2 present [6]MIL-STD-882A hazard severity levels for the physiological effects, as delineated in table 1-1 of [7]MIL-STD-454G, of ac or dc electrical shock potentials to adult males. These figures do not indicate that women and persons who are below average weight are susceptable to more severe physiological effects from an electrical shock. After examining figures B-1 and B-2, it is evident that the physiological effect and associated hazard severity levels depend upon the body and contact resistance, the applied voltage potential, and whether the power source is ac or dc. The body and contact resistance depends upon several exposure factors: the probable current path through the body, the duration of exposure, body weight, potential contact surface area and whether the contact area is wet or resulting in a particular exposure, can be assigned a qualitative hazard probability level consistent with the requirements of [6]MIL-STD-882A. Using figure B-3 it is possible to estimate the body and contact resistance for most common exposures. Thus, having estimated the body and contact resistance for a potential exposure, and knowing the power source and applied voltage, the appropriate figure may be used to determine the probable physiological effect and resultant hazard severity level. This hazard severity level and the qualitative hazard probability level already established are used to complete the hazard analysis procedure described in appendix A of this document.

7. MIL-STD-454G, Standard General Requirements for Electronic Equipment, 15 March 1980

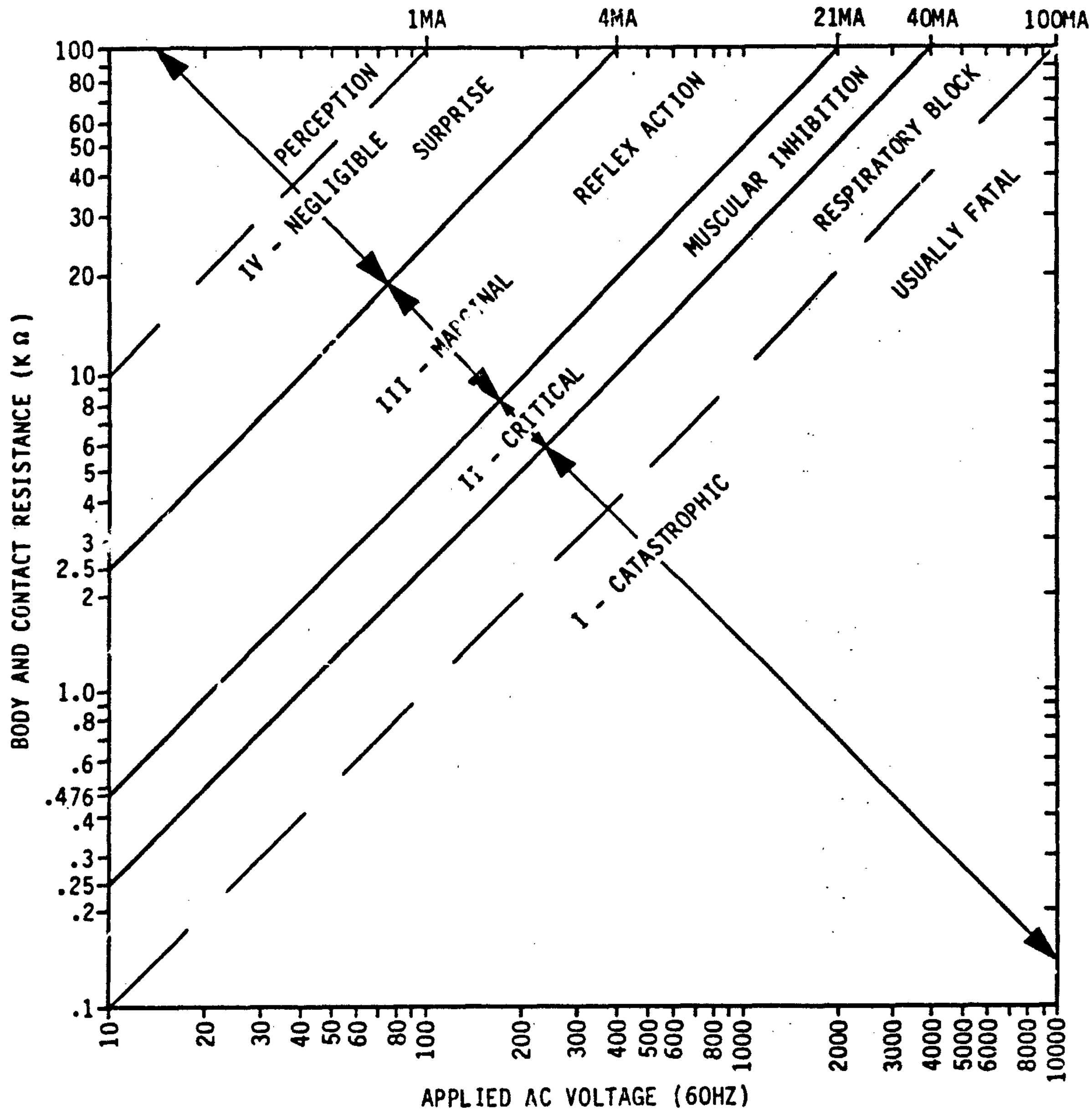


Figure B-1. Hazard severity determination from ac electrical shock.

Sources: DH 1-6; 8/; MIL-STD-454G; EPG Safety Branch

8/; AFSC Design Handbook, System Safety 20 December 1978.

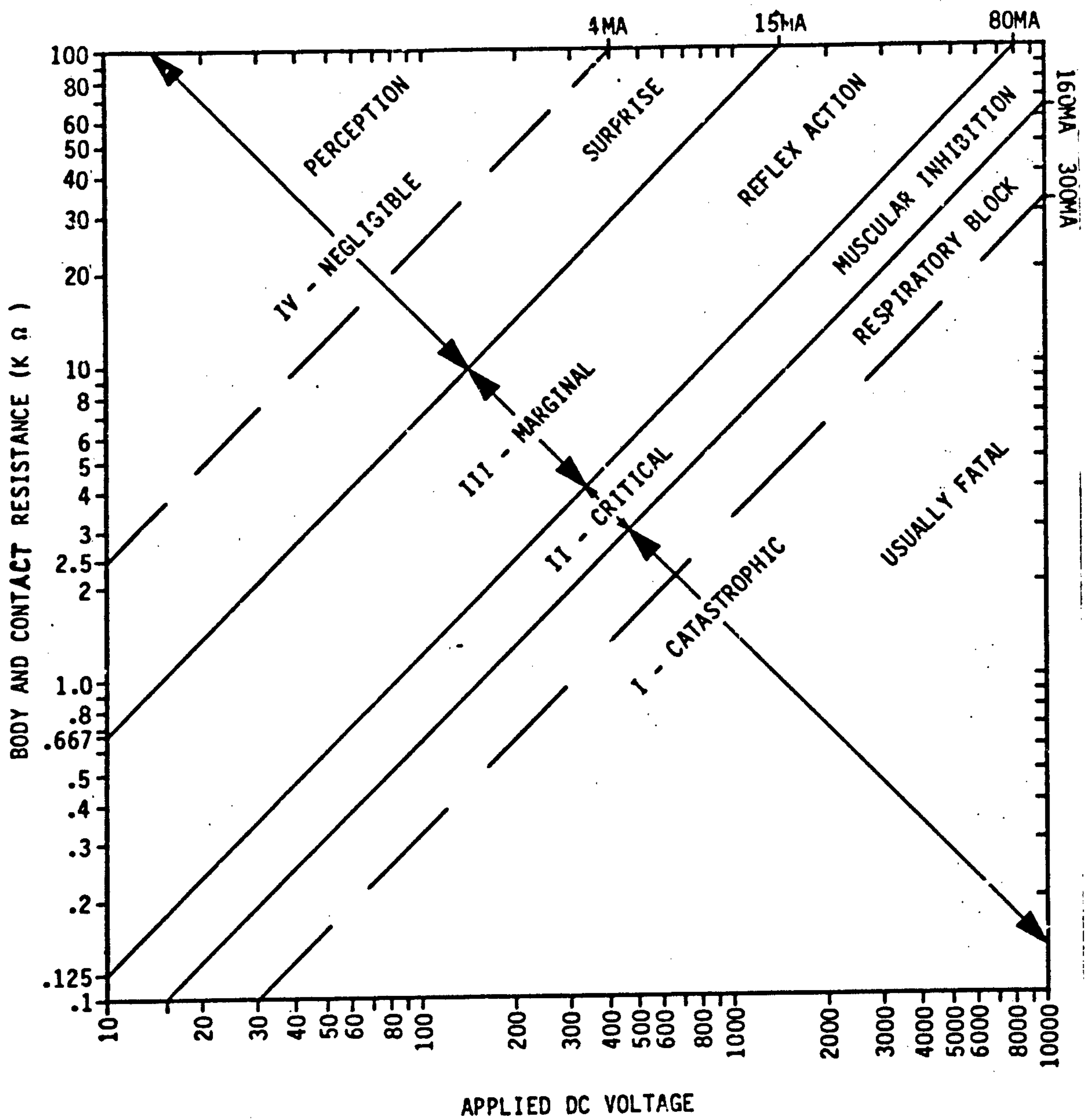
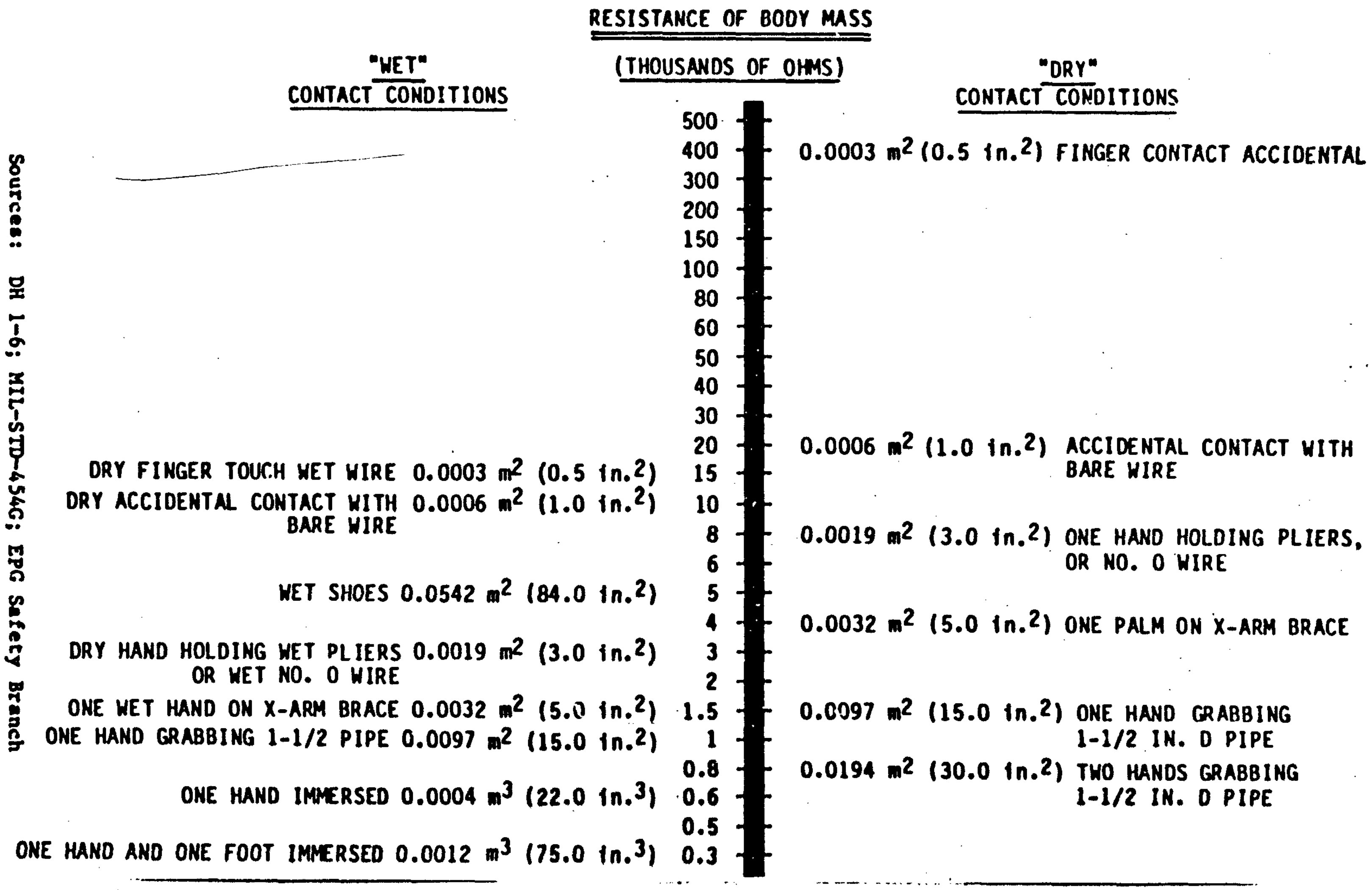


Figure B-2. Hazard severity determination from dc electrical shock.

Sources: DH 1-6; 8/; MIL-STD-454G; EPG Safety Branch

8/; AFSC Design Handbook, System Safety 20 December 1978.



Sources: DH 1-6; MIL-STD-454G; EPG Safety Branch

Figure B-3. Typical body surface contact resistance.

APPENDIX C.

SYSTEM SAFETY CHECKLIST

YES | NO | NA

APPENDIX C

SYSTEM SAFETY CHECKLIST

ELECTRICAL

1. Are green indicator lamps provided to indicate ".ower on" situation to the portable equipment?

2. Does shielding end a sufficient distance from exposed conductors to prevent shorting or arcing between the conductor and the shielding?

3. Are electrical connectors designed so that it will be impossible to insert the wrong plug in a receptacle or other mating unit?

4. Where design consideration require plugs and receptacles of similar configuration in close proximity are mating plugs and receptacles suitably coded and marked to clearly indicate mating connectors?

5. Does the design of plugs and receptacles preclude exposure to electrical shock or burns when normal disconnect methods are used?

6. Are exposed male plugs de-energized after being disconnected from the female receptacle?

7. Are plugs and receptacles of dissimilar configuration used where explosive items are contained in the major unit?

8. When equipment is designed to operate on more than one type of input power, are adequate precautions taken to prevent connection or use of improper power?

9. Are single phase power cables properly color coded? [Black (hot), white (neutral), green (ground)]

10. Are 3-phase cables coded as phase 1-black, phase 2-red, phase 3-blue, neutral-white and ground-green?

11. Do meters have protection against high voltage potential or current at the terminals in the event of meter failure?

12. Are current and voltage overload protective devices provided?

13. Are power busses supplying 25 amperes or over protected against accidental short circuiting?

14. Are all external parts, surfaces, and shields, exclusive of antenna and transmission line terminals at ground potential at all times?

YES	NO	NA	
			15. Is the path to ground from the equipment continuous and permanent via a ground wire?
			16. Is the ground wire color coded green or green with yellow stripes?
			17. Does the ground wire have ample ampacity to conduct safely any currents that shall be imposed upon it?
			18. Is the ground wire terminated at both ends in the same manner as the other power conductors?
			19. Is the ground wire electrically insulated from all live conductors and the ac power return conductor (neutral)?
			20. Is the impedance of the ground system sufficiently low to limit the potential above ground and to facilitate the operation of the overcurrent devices in the circuit?
			21. Does the ground system have sufficient mechanical strength to minimize the possibility of ground disconnection?
			22. Is the ground connection to the chassis or frame mechanically secured by one of the following methods:
			(a) Secured to a spot welded terminal lug.
			(b) To a portion of the chassis or frame that has been formed into a soldering lug.
			(c) By the use of a terminal on the ground wire secured by a screw, nut, and lockwasher.
			23. Is a grounding stud (hand-operated quick disconnected nut) provided for all transmitting equipment to permit attachment of a portable ground rod?
			24. Are antenna and transmission terminals at ground potential except for RF voltages?
			25. Do plugs and convenience outlets for use with portable tools and equipment have provisions for automatic grounding the frame or case of tools and equipment when the plug is mated with the receptacle and the grounding pin shall make first, break last?
			26. Is any part of the supply voltage directly connected to the chassis.

YES	NO	NA	
			27. Are wires and cables adequately supported and terminated to prevent shock and fire hazard?
			28. Are dc power connections color coded and marked for polarity?
			29. Are operating personnel protected from accidental contact with voltages in excess of 30 volts rms (ac) or dc?
			30. Is personnel protection provided from leakage current in excess of 5 milliamperes peak ac or dc from any accessible conductive parts of the equipment to either pole of the power source for any position of the power switch?
			31. Does each contact, terminal or like device having voltages between 70 and 500 ac or dc with respect to ground, have barriers or guards to minimize accidental contact by direct support or operator maintenance?
			32. Are barriers or guards protecting voltages 70-500 volts clearly marked to indicate approximate normal highest voltage encountered upon its removal: "CAUTION HIGH VOLTAGE, XXX"? (The letters shall be yellow gothic capitals on a black background and the voltage shall be black on yellow.)
			33. Are assemblies operating at potentials in excess of 500 volts ac or dc completely enclosed from the remainder of the assembly?
			34. Are nonbypassable interlocks provided on enclosures who have terminals operating above 500 volts ac or dc and maintenance accomplished below depot level?
			35. Are enclosures for potentials in excess of 500 volts clearly marked "DANGER HIGH VOLTAGE, XXX VOLTS"? (Letters shall be gothic capitals, color white with a red background and voltage shall be black on white.)
			36. Do all high voltage circuits and capacitors (stored energy $\geq$ 1/4 Joules) discharge to 30 volts in 2 seconds or less.
			37. If high voltage circuits and capacitors do not discharge to 30 volts in 2 seconds or less, are devices provided to automatically discharge them when the case or rack is opened?
			38. Are test points provided in equipment where measurement of potentials in excess of 300 volts is required?
			39. Does the design of test points require plug-in of test instruments? (Not clamp-on.)

YES NO NA

40. Does the RF transmitter output terminals, antennas and other devices that carry harmful RF voltage protected in the same manner as voltages in the 70-500 volt range?

SWITCHES

1. Is a main power on-off switch provided which cuts off all power to the complete equipment?

2. Does the main power on-off switch break all poles of the source except the grounding conductor when in the off position?

3. Is the main power on-off switch clearly identified?

4. Is the main power on-off switch located on the front panel of the equipment?

5. Is the power input side of the mainpower on-off switch and the incoming power line connectors protected from accidental contact by operators or maintenance personnel?

6. Are equipment power on-off switches located in a manner to preclude activation of equipment by accidental contact?

7. Are safety switches provided which will deactivate associated mechanical drive units for the purpose of disconnecting these units without disconnecting other parts of the equipment?

8. Can the power be cut off while installing, replacing or interchanging a complete equipment, assembly or part thereof?

9. Are emergency controls placed in readily accessible locations and clearly identified?

10. Is the sheltered system provided with a master power circuit breaker that will cut off all power to the shelter?

MECHANICAL

1. Do exposed gears, cams, levers, fans and belts have adequate safety covers?

2. Are expandable and collapsible structures such as shelter, jacks, supports, masts, tripods, etc., designed to prevent possible injury to personnel?

3. Does the design provide positive means to prevent mismating of fittings or couplings of fuel, oil, hydraulic and pneumatic lines?

YES	NO	NA	
			4. Are doors and other openings with their catches, hinges, supports, fasteners, and stops designed to prevent possible injury to personnel?
			5. Are cathode ray tubes provided with implosion protection?
			ENVIRONMENT
			1. Under all maintenance conditions, are exposed parts temperature less than 60°C at an ambient temperature of 25°C?
			2. Under all conditions of operation, is the temperature of front panels and operating controls less than 49°C at 25°C ambient temperature?
			3. Are parts/components free from the potential for release of toxic, corrosive or explosive fumes or vapors?
			4. Are noise levels less than 85 dbA at operators normal position?
			5. Is the use of glass fiber materials avoided in outer covering or cables, wires or other components?
			RADIATION
			1. Are warning labels provided to indicate the hazard range of RF (300-3000 MHz) components producing a power density 10 mW/cm^2?
			2. Have all devices having circuitry in excess of 15,000 volts been evaluated for X-radiation?
			3. Are all X-ray producing devices provided with shields which reduces exposure of personnel to 0.25 mR/hr or less?
			4. Are X-ray producing devices and the components in which they are located posted with an X-radiation hazard warning symbol?
			5. Have tests been made to insure no radium has been used in the equipment?
			6. Is the equipment free of radioactive material? (Tubes, knobs, meters, dials, scales, markings, etc.)
			7. Are radiation markings and labels affixed to all parts or components containing radioactive material? NOTE: If radioactive material is present a "wipe" test may be required to determine if removable contamination is present.
			8. Are protection devices and warning signs provided against all sources of potentially hazardous radiant energy (ultraviolet, infrared, high energy visible, etc.)?

YES | NO | NA

GENERAL

1. Are fastenings and methods of securing equipment to walls and racks sufficiently strong to prevent breakaway, falling and accidental pulling out?

2. Have sharp or overhanging edges and corners that may cause injury to personnel been eliminated?

3. Is the equipment designed so that the center of gravity, configuration, legs and supports make the equipment unlikely to tip over from imbalance or strong wind?

4. Is the weight distribution such that the equipment is easy to handle, move or position?

5. Is the equipment provided with suitable carrying handles?

6. Is equipment weighing over 35 lbs labeled to indicate lifting requirements?

7. If equipment is to be used in hazardous atmospheres (explosive gas or vapors, combustible dusts, ignitable fibers and flyings) has it been designed to preclude accidental ignition of such atmospheres?

8. Are critical warning lights isolated from other less important lights for best effectiveness?

9. Are audible warning signals distinctive and unlikely to be obscured by other noises?

10. Are control circuits and warning circuits designed so they are never combined?

11. Where item design includes the use of pressurized systems and components, are safety and/or relief valves, controls and other safety features provided?

12. Is non-shatterable glass used in cases where the use of glass is essential to equipment operations or where glass breakage would endanger personnel?

ANTENNAS

1. Is insulation provided to protect personnel from RF burns?

2. Are antenna tips designed to prevent puncture wounds?

YES	NO	NA	
			3. If vehicle mounted antennas could contact overhead electrical lines, are warning labels provided?
			4. Are lock-out devices provided for antennas operated from remote locations?
			SHELTER, VANS, TRAILERS
			1. Does vehicle weight distribution comply with technical requirements?
			2. Does lateral stability comply with technical requirements?
			3. Does the mounting of shelter on vehicles provide sufficient mechanical strength to minimize potential equipment damage?
			4. Are entries and exits free of obstructions?
			5. Is an emergency exit provided and identified?
			6. If personnel are required to work on the shelter roof, are ladders, non-slip roof surface, and guardrails or chains provided?
			7. Are steps with handrails provided to permit safe ingress and egress?
			8. When semi-trailers are detached from towing vehicles to dolly wheels or landing gear provide adequate support?
			9. Do instruction manuals or instruction plates provide adequate instructions for placement of semi-trailers when detached from towing vehicle?
			10. In the event the trailer becomes detached from towing vehicle are safety chains or other devices provided?
			11. Are accessories being transported properly secured to prevent possible damage when the vehicle is in motion?
			12. If standard military vehicle has been modified, is the vehicle still capable of satisfactory and safe operation?
			13. Will lifting rings and/or slings of equipment support the total weight of the shelter and the installed equipment?
			14. Are shelter ground rods and straps provided?
			15. Is a ground stud provided at the power entry box?

YES	NO	NA	
			16. Is the ground stud identified by a label or other marking?
			17. Are all other convenience outlet ground pins hard-wired to the ground stud?
			18. Does the power cable have a green ground wire which is not used as a current carrying conductor or power return?
			19. Does all GFE have the ground isolated from neutral (except generators)?
			20. Is the power cable ground wire connected to the ground stud?
			21. Is a power on indicator light provided that is extinguished only when the power source to the shelter is terminated?
			22. Are indicator lights properly color coded? (Information, white; caution, amber; danger, red; and power-on, green)
			23. Are remotely located assemblies provided with safety switches to allow independent disconnection of the equipment?
			24. Do floor surfaces provide adequate non-slip characteristics?
			25. Do floor surfaces provide adequate insulating characteristics?
			26. Have fire hazards been kept to a minimum?
			27. Are fire extinguishers in an accessible location?
			28. Do hatches, covers, lids, and doors have a positive lock for the open position?
			29. Are provisions provided to secure hinged and sliding components against accidental movement?
			30. Are limit stops provided to prevent drawers from accidently being completely withdrawn?
			31. If multifuel heaters are provided:
			(a) Is the fuel line as short as possible inside the shelter?
			(b) Is there a shut off valve inside the shelter?
			(c) Is a fuel line and Jerry-can adapter provided for connection to the external fuel source?

YES	NO	NA

(d) Is the heater exhaust pipe located as far as possible from the fuel intake valve?

(e) Does the routing of the heater exhaust pipe preclude a concentration of carbon monoxide in the shelter?

(f) Are fuel supply cans located outside the shelter and away from the heater?

32. If battery compartments are located in the shelter:

(a) Are they enclosed and provided with forced air ventilation to the outside of the shelter?

(b) Is a device provided to warn personnel that the battery vent lid or door is closed or that the forced air ventilation fan is not working?

(c) Is the compartment labeled to warn personnel of the potential presence of explosive gas accumulation?

(d) Is there a warning label affixed to remove battery if stored over 30 days?

33. On vehicle mounted shelters, is the vehicle exhaust located in a manner to preclude entry of carbon monoxide into the shelter?

34. Does the equipment installation provide adequate overhead clearance for personnel?

35. In the event of a power failure, is emergency lighting provided?

APPENDIX D

TECHNIQUES FOR CALIBRATING TRANSDUCERS TO MEASURE AIRBLAST OVERPRESSURES

1. Transducer Calibration.

a. All transducers will be calibrated before and after the test in a manner consistent with their time constant, i.e., sinusoidal pressure generator, pulse calibrator, dead weight tester, or shock tube.

b. All calibration methods used will be traceable to the National Bureau of Standards.

c. When pentolite calibration is used, a minimum of three pentolite charges will be used before and three after the test.

2. Calibration Methods.

a. Shock Tube Calibration. A convenient means of simulating blast experiments in the laboratory is the shock tube. As shown in Figure D-1, the pressure-versus-time waveforms of these two pressure sources are different. The shock tube produces a flat-topped pressure-versus-time curve. The duration of the flat portion is a function of the length of the driver portion of the shock tube. To perform shock tube calibration, measure velocity of the shock wave in the tube, and calculate the overpressure level that corresponds to that velocity, taking into account air temperature, barometric pressure, and relative humidity. The formula for shock tube calibration is:

$$\text{Overpressure} = \text{atmospheric pressure} \times 7/6 \times \text{quantity } (m^2 - 1)$$

when: m = measured velocity of shock wave divided by the speed of sound in air

Four measurements are required to calculate the side-on pressure of a shock wave: baseline length, transit time, ambient temperature, and ambient pressure. Of these four, air temperature and transit time are critical.

Shock tube calibration of transducers has two disadvantages: sensitivity to measurement errors, and difficulty in determining which point (to within 1%) on a signal corresponds to the calculated pressure level. The accuracy of this technique ranges from $\pm$2-5%.

b. Static Pulse Calibration. With this method of calibration, pressurized air is stored in a large tank; the air pressure level can be accurately measured with a static pressure gage. The test transducer is then connected to a 3-way quick-acting valve that normally exposes the transducer to ambient atmospheric pressure. When the valve is actuated, the transducer is exposed to the pressure in the large tank. The valve is designed so that the volume change caused by exposing the transducer to tank pressure is negligible. The transducer is therefore exposed to a pressure step equal to the pressure level indicated by the tank static pressure gage.

Static pulse calibration permits very accurate measurement of exact calibration pressure level, but acoustic resonance in the plumbing of the calibrator causes ringing in the transducer signal, which makes it difficult to determine the exact output level of the transducer for a given pressure level. Another problem in-

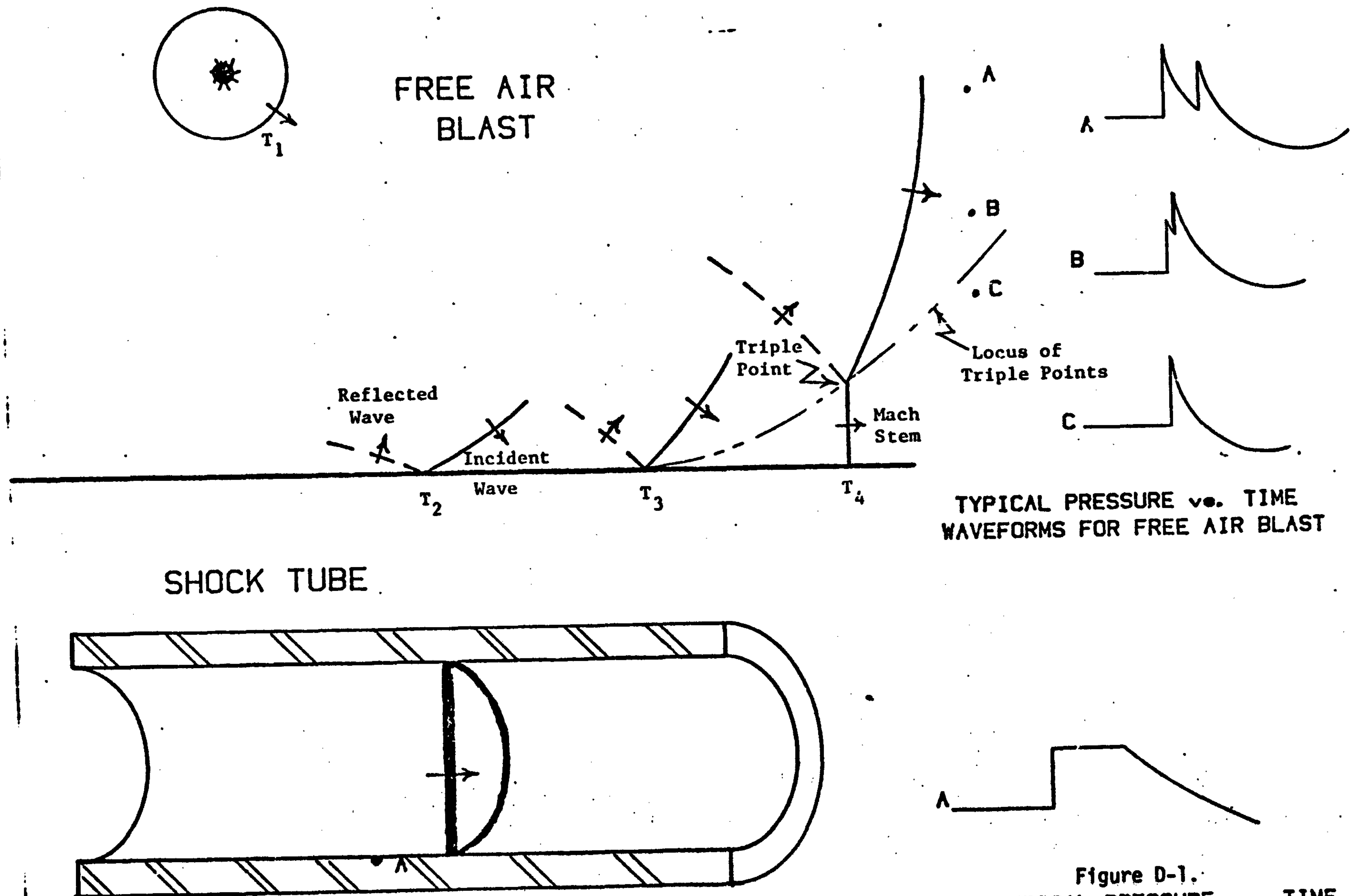


Figure D-1.
TYPICAL PRESSURE vs. TIME
WAVEFORM FOR SHOCK TUBE

troduced by the static pulse calibrator is the thermal effect of adiabatic compression. The accuracy of this technique is ±2%.

c. Sinusoidal Pressure Calibration. This unit is essentially a high-intensity microphone calibrator which is an enclosed load speaker. An electrical sine wave input to the coil causes the piston to generate a sinusoidal pressure variation. A calibrated resistor is used to monitor the input current to the coil and produces a calibrated electrical output that indicates the magnitude of the pressure that the transducers are sensing.

The transducer signal produced during sine wave calibration can be accurately read with a voltmeter or digital transient recorder. The calibrator is portable, so calibration can be performed on-site. Because calibration is performed well above the low-frequency rolloff point, the time constant of AC-coupled transducers does not affect calibration. The fact that sine wave calibration is conducted at a relatively low level (2.4 kPa rms) introduces several problems. This level is often at or below the low amplitude limit of the transducer's pressure range, which means the signal-to-noise ratio may be small. Also, transducer nonlinearity becomes a problem at low pressure levels, and it has been discovered that the small piece of electrical tape used for thermal protection of the transducer can cause errors in low-level sine wave calibration. This is particularly true if the tape is old and not sticking well. The accuracy of this technique is ±2%.

d. Pentolite Calibration. With this method for calibrating blast gages, the gage is exposed to a known level of pressure, and the corresponding gage response is obtained. Calibration firings are usually set up to provide pressure levels that are comparable to the anticipated level of pressure to which the gage will be exposed in test firings. The actual pressure level at the gage position is determined by measuring the velocity of the blast wave at that point, and computing the pressure by means of the Rankine-Hugoniot equation. The gages identified in the later detailed discussion as "velocity gages" are pressure-sensitive gages used to measure the time required for the pressure wave to advance a measured distance, thus providing a measure of blast wave velocity. Ordinarily, calibration "shots" are detonations of bare spherical charges of pentolite (see Figure D-2), and desired calibration pressure levels are obtained by selecting the size of charge and distance from the charge. A report[8] by the Ballistic Research Laboratories shows the blast parameters as a function of scaled distance from the charge, obtained from tests with bare charges of spherical pentolite. The scaled distance (Z) is the relationship of the radial distance (R) from the charge to the gage, divided by the cube root of the effective charge weight (W). For small charges (1 lb [454 g] or less), steep pressure gradients exist at high pressure levels. At low pressure levels, mathematical sensitivity of the equation to small measurement errors makes this method difficult to use. For these reasons, pentolite is the least desirable calibration method. The accuracy of this technique is ±15%.

To determine the velocity of the shock front at the pressure gage position, two velocity pickup gages are positioned near each blast gage to be calibrated. One velocity pickup gage should be located 0.3 to 0.5 m forward (closer to the charge) and the other velocity pickup gage should be the same distance behind the blast gage. The illustration of Figure D-3 presents the positions of the three gages relative to the charge.

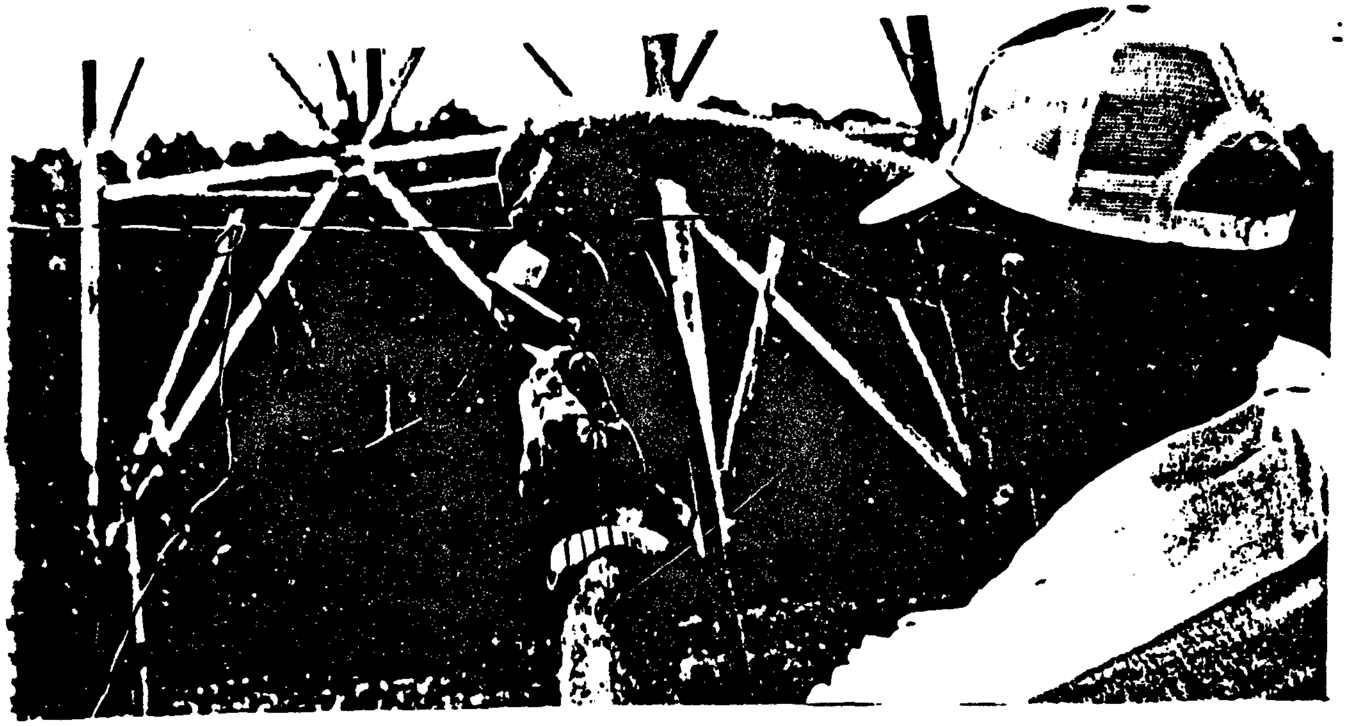


Figure D-2. Bare spherical charge of pentolite.

The velocity of the shock front (U) obtained at each blast gage position in the calibration firings is then used in the Rankine-Hugoniot equation.

$$P_v = \left[\frac{2\gamma}{\gamma + 1}\right] P_o \left[\left(\frac{U \pm K}{C}\right)^2 - 1\right]$$

when: P_v = peak overpressure derived from shock front velocity (U) (kPa)

γ = ratio of specific heat of air in front of shock front to that behind it; use a value of 1.4

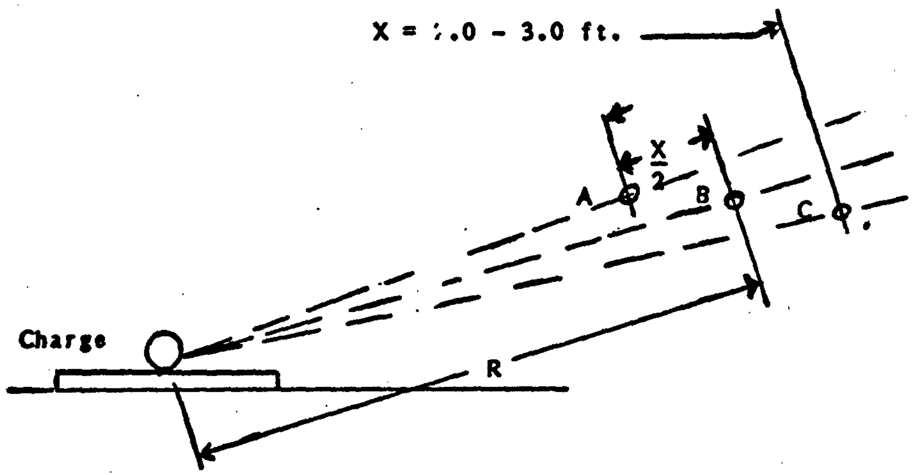
P_o = local ambient atmospheric pressure (kPa)

U = shock front velocity (m/s)

K = wind vector component orthogonal to wave front (m/s)

C = sound velocity through air at local ambient temperature (m/s)

This provides the peak overpressure to which the blast gage was subjected during the calibration phase of the test.



A = velocity gage (face-on)
B = blast gage
C = velocity gage
R = distance from charge

Figure D-3. Position of blast and velocity pickup gages during calibration.

Blast gages are calibrated before and after each blast test. Normally, no less than three calibration charges are detonated for each gage for the before-fire calibration, and three charges for the after-fire calibration. After all calibration testing is completed, the average K_a should be determined for each gage, and this value used for computations of overpressure for all test rounds.

The purpose of the before-fire calibration is to determine whether the gage has been subjected to accidental damage and whether the electrical characteristics of the crystals have been altered because of dormancy. After-fire calibrations are required to determine whether the gage characteristics have been altered because of fatigue or whether the gages have been damaged during the test by flying debris such as stones, dirt, unburned propellant, or fragments.

Data cards should be maintained for each gage to provide a history of gage response. Each card would contain the following information.

"Date Gage No. K_a Pressure Level Type of Test"

As the calibration test data are recorded, the present gage sensitivity K_a should be compared to the average K_a of the gage history. Variations of 10% may be

expected, but greater differences should be investigated with the possibility of having the gage rebuilt.

3. Calibration Shot(s). Bare charges may be detonated at the test site to check out the instrumentation system and to calibrate the pressure gages. Such detonation also serves to detect anomalies at the test site that may develop from shock wave reflections from nearby structures and equipment. These calibration shots make it possible to ascertain which test data may have been influenced by fragment damage or by shock waves impinging on a gage. As previously stated, at least three calibration charges are normally detonated before the test, and three charges detonated afterwards. Observe the following procedure:

a. Determine the weight of a bare charge or other suitable explosive (e.g., pentolite) required to produce about the same overpressure as expected from the test item.

b. Position the bare charge at the same height selected for the test item.

c. Mount the pressure gages as in Paragraph 5.2.1.c(2), with the calibration charge at a distance from the gages comparable to the distance to be used in the actual test.

d. Detonate the explosive.

e. Correct all anomalies detected during calibration shot(s) before testing the item.

f. Record the following:

(1) Oscillograph/chronograph readings as obtained in c above
(2) Type and weight of charge
(3) Height of charge above ground
(4) Distance of gages from the center of the charge
(5) Type of gage used and height above ground
(6) Angular location of gages
(7) Location of fragment guards, if used
(8) Wind velocity and direction
(9) Air temperature, barometric pressure and relative humidity

APPENDIX E

BLAST OVERPRESSURE DATA REDUCTION/PROCESSING

Data Processing.

a. Direct analog-to-digital data conversion will be through a low-pass 40-kHz Bessel-type filter, 36 dB/octave rolloff.

b. The digitizing rate shall be at least 160,000 samples/second or faster.

c. All data will be scaled to standard conditions of atmospheric pressure: 101.35 kPa (14.7 psi) and ambient temperature: 288° K (15° C) with Sach's scaling laws. The sea level values (superscript o) scaled from the data parameters measured at an altitude (superscript h) are found as follow:

peak overpressure, $$P_s^o = P_s^h \left(\frac{101.35}{P_o^h}\right)$$

duration, $$t^o = t^h \left(\frac{P_o^h}{101.35}\right)^{1/3} \left(\frac{T_o^h}{288}\right)^{1/2};$$

and for impulse, $$I^o = I^h \left(\frac{101.35}{P_o^h}\right)^{2/3} \left(\frac{T_o^h}{288}\right)^{1/2}$$

d. Analog-to-digital converter shall have a 10-bit word size or greater.

Overpressure Conversions. Conversions between side-on and face-on overpressures can be made according to Rankine-Hugoniot equation[9] as follows, provided that:

$$\frac{P_s}{P_o} < 20$$

$$P_r = P_s \left(2 + \frac{6\, P_s/P_o}{7 + P_s/P_o}\right)$$

when: P_r = face-on or normally reflected overpressure (kPa)

P_s = side-on overpressure (kPa)

P_o = ambient atmospheric pressure (kPa)

Units of Pressure Measurement.

Pressure (force per unit area) is expressed in various units, but the four most frequently used are:

pounds per square inch (psi)
pascals (newtons per square meter)
atmospheres (dimensionless ratio of measured pressure to standard sea-level atmospheric pressure)
decibels (dimensionless logarithmic ratio of measured pressure to a reference pressure)

Figure E-1 shows the relationship between two ways of expressing pressure. Most equipment in the United States is calibrated in psi. In the interest of international standardization, the Army has adopted the pascal as the standard unit of pressure. The decibel (dB) is a unit commonly associated with hearing. The reference pressure for dB is 20 micropascals, which is estimated to be the lowest pressure detectable by the human ear. A few convenient relationships should be remembered when using decibels:

A difference of 0.1 dB is a 1% discrepancy.
A difference of 1 dB is a 12% discrepancy.
A 2:1 ratio of pressure (which is either a 50% or a 100% discrepancy, depending on whether the small number or the large number is used as a reference) is a difference of 6 dB.
A difference of 20 dB is one order of magnitude of pressure.

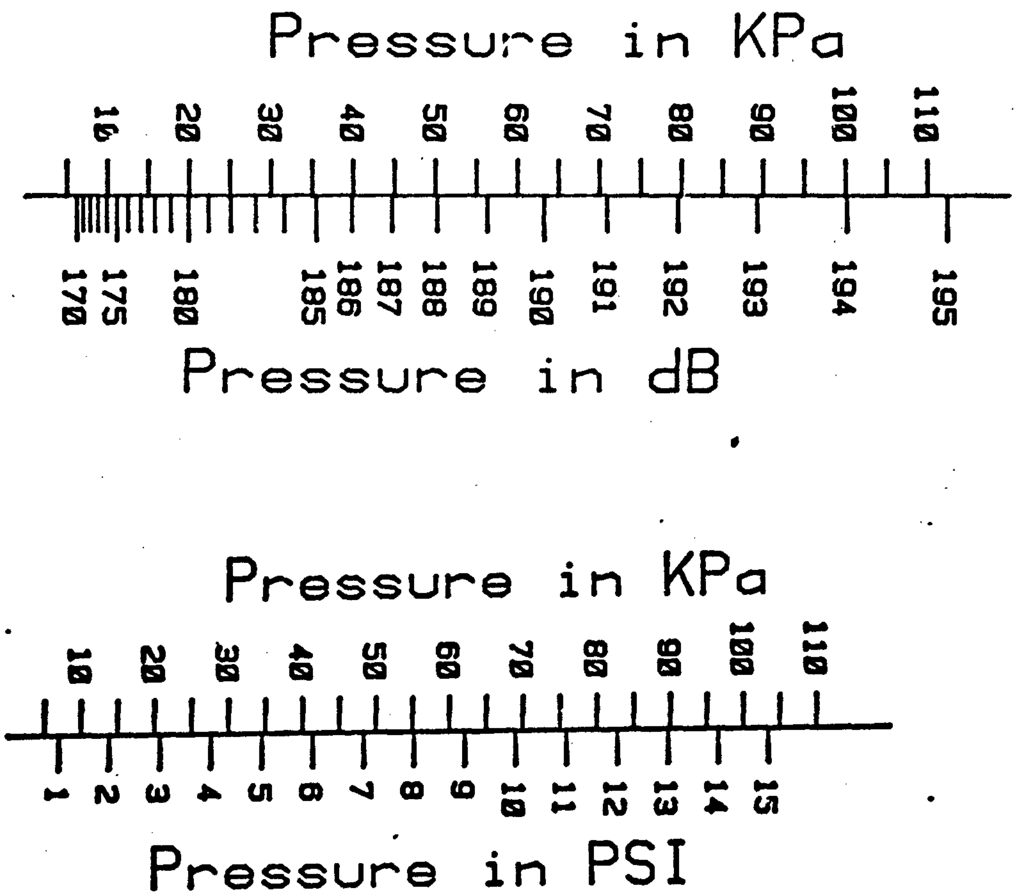


Figure E-1. Units of Pressure.

APPENDIX F

SHOCK WAVE VELOCITY

The velocity overpressure relationship between the peak overpressure and the shock wave propagation velocity is obtained from the Rankine-Hugoniot equation for ideal gas relation:

$$P_s = P_o \frac{(2\gamma)}{\gamma + 1} \left[\left(\frac{U + K}{C_o} \right)^2 - 1 \right]$$

when: P_s = peak overpressure (kPa) (side-on)

P_o = atmospheric pressure ahead of the shock (kPa)

U = velocity of shock front propagation (m/s)

C_o = velocity of sound in undisturbed air (m/s)

γ = 1.40 (ratio of specific heat for air)

K = component of wind velocity (m/s)

To determine the velocity of sound in undisturbed air, use the relationship[10]:

$$C_o = \left(1088.1 + \frac{t}{273} \right) \bullet \left(1 + 0.49 \frac{P_w}{P_a} \right)$$

when: C_o = velocity of sound in undisturbed air (m/s)

t = air temperature (° C)

P_w = partial pressure of water vapor

P_a = partial pressure of air

(NOTE: Temperature and relative humidity measurements must be made at the site.)

If the firing is conducted on a windy day, further corrections for wind velocity and direction must be considered in the computations for the velocity of sound in air. If this is necessary, refer to[11].

To determine shock wave velocity (U), time the passage of the shock wave over the interval between the velocity gages, and calculate the average velocity.

It should be noted that at low pressure levels, the equation for calculating overpressure from shock wave velocity becomes so sensitive to small errors in temperature and velocity measurement, that this technique becomes impractical.

APPENDIX G

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